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Now it happens that the region cleared by the ancient inhabitants has a tough clayey soil of such a nature that it bakes dry and hard in the dry season; grass and weeds dry up, and young trees that would germinate in the wet season are as regularly killed in the dry. These Sabanas show numerous ancient remains; and these and also the pine forests deserve to be thoroughly examined by archæologists. Much might be learned to shed light on the studies already made on the more modern ruined cities and sculptured temples of Central America.

MOUNTAIN-UPTHRUSTS.

BY CHARLES A. WHITE.[1]

CERTAIN of the mountain ranges of the western portion of our national domain exhibit in a clear and striking manner the evidence that they have originated in uplifted folds of the earth's crust. One of the simplest and most characteristic of these orogenic folds is the one in which the Uinta Range of mountains originated.

Other uplifts of a similar character have occurred, but which, having been of limited longitudinal as well as lateral extent, have resulted in comparatively small clusters of mountains, and not in mountain ranges proper. The Black Hills of Dakota have originated in one of these circumscribed uplifts.

In Northwestern Colorado two uplifts occur which, so far as the character of the displacement and of the formations involved are concerned, are similar to those which have just been referred to; but they have occurred within such narrow limits, respectively, that they have each resulted in only a single mountain. The limits of each of these uplifts are so sharply defined, and the amount of vertical displacement of the strata involved is so great, that I have designated them as upthrusts.

A description of these upthrusts is the special object of this article. But as they are structurally connected with the great Uinta fold and with other neighboring displacements, it will be necessary to devote a considerable part of it to their description also.

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[1] Published by permission of the Director of the U. S. Geological Survey. The substance of this article will be embraced in one which is to appear in his Ninth Annual Report.

The great Uinta fold has usually been described as terminating abruptly in Northwestern Colorado. As a conspicuous fold it does so terminate there; but continuous with its axis to the eastward there is a long, gentle anticlinal, which reaches by a broad curve to the foot-hills of the Park Range—a western porton of the Rocky Mountain system. This I regard as a continuation of the Uinta fold far beyond its reputed termination, and also, in connection with other facts, as indicating structural relationship between the Uinta and Park Ranges. I therefore divide the Uinta fold into two portions—namely, the Uinta fold proper, and the inceptive portion of the same.

The Uinta fold proper is about one hundred and fifty miles in length, and from thirty to forty miles in width at the extreme limit of the upturned strata at either side. Its western end is blended with the Wasatch Range in Utah, which it meets at nearly right angles. Its eastern terminus is about thirty miles within, and east of, the western boundary of Colorado, and about the same distance from the northern boundary. Its axis, except the slight southward inclination of its eastern end, is approximately east and west, and at nearly right angles with that of the Park Range.

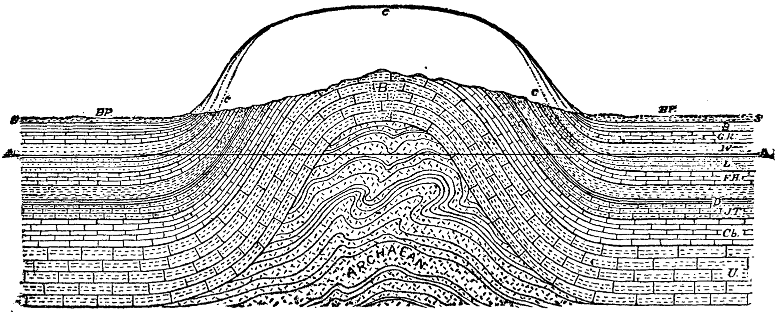

FIG. 1.—A generalized section across the Uinta Fold.

This great fold is remarkable for its simplicity, its almost entire freedom from lateral complications, and for the extent of its vertical displacement. Its type of uplift is also peculiar, the sides being abrupt and the top broadly convex. The accompanying generalized section across the fold (Fig. 1) indicates its general character, and also shows the formations which are involved in it.

The irregular line, SS, represents the land-surface, and the straight line, AA, the sea-level. The dotted line at either side of B represents the depth to which Green River has cut its cañon in traversing the Uinta Range. The dotted lines above the surface-line represent the portions of the formations which have been eroded, and the extent to which they would have been elevated in the fold if they had suffered no erosion.

The dotted line, ccc, is continuous with the top of the Laramie group. This indicates that all the formations below that line were fully involved in the fold; while the other dotted lines which lap upon either side represent the eroded portions of the four fresh-water Tertiary formations, which were successively less and less involved in the fold as the elevation progressed.

The initial U. indicates the Uinta Sandstone; Cb. indicates the Carboniferous; J. T., the Jura-Trias; D., the Dakota Group; Co., the Colorado Group; F. H., the Fox Hills Group; L., the Laramie Group; W., the Wasatch Group; G. R., the Green River Group; B., the Bridger Group, and B. P., the Brown's Park Group.

The following table gives the names and the ascertained thickness of the formations which are more or less involved in the fold, or which occur in its immediate vicinity:—

Cenozoic	Tertiary.	Brown's Park Group	1200–1800	feet.
		Bridger Group	100–2000	“
		Green River Group	1400–2000	“
		Wasatch Group	2000–2500	“
Mesozoic	Cretaceous.	Laramie Group[1]	2000–3000	“
		Fox Hills Group	1800	“
		Colorado Group	2000	“
		Dakota Group	500	“
	Jura-Trias		2500–5000	“
Palæozoic	Carboniferous		3000–4000	“
	Uinta Sandstone		12000–14000	“
Archæan			....	

The facts upon which the construction of the foregoing generalized section is based indicates that all the formations, from the Uinta Sandstone to the Laramie Group (inclusive), were fully involved in the great fold, and that the four fresh-water Tertiary formations are only partially involved in it. The latter formations were respectively deposited in large fresh-water lakes, the existence, height and limits of each of which were determined by the successive changes in the configuration of the land-surface, as elevation and degradation progressed.

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[1] I here provisionally place the whole of the Laramie Group with the Cretaceous formations.

Again, although the Archæan rocks are theoretically represented in that section, they have not been brought to view in the axis of the fold, because even the immense erosion which the uplifted strata have suffered has not been sufficient to reach them there.[1] Therefore, in estimating the amount of vertical displacement which has taken place in the Uinta fold, I have reference only to the formations from the Uinta Sandstone to the Laramie Group (inclusive).

Now, referring to the foregoing table, we find that the minimum thickness of these formations aggregates twenty-three thousand eight hundred feet. Add to this five thousand feet for the height above the level of the sea at which the lowermost strata of the Uinta Sandstone have been observed, and we have an aggregate of twenty-eight thousand eight hundred feet. The evidence seems to be conclusive that the elevation of the fold began immediately upon the close of the Laramie period; and it is confidently assumed that none of its strata were then much if any above the level of the open sea. Hence the conclusion that the full amount of vertical displacement in the Uinta fold has not been less than twenty-eight thousand eight hundred feet.

The evidence derived from a study of the great fold seems also to be conclusive that its elevation was continued between the close of the Laramie period and the close of the Tertiary; and other evidence is equally conclusive that continental elevation was continued during the same time. That is, it is assumed that the orogenic movements which have resulted in the production of the Uinta and other mountain-making folds were approximately synchronous in their origin and coeval in their duration with the epirogenic[2] movements by which the great continental area upon which those folds now rest was raised to its present elevation above the sea.[3]

[1] Archæan rocks are exposed within a limited area upon the northern side of the fold; but they were evidently a part of an uplift which was older than the fold.

[2] Etym., *Ηπειρος*—mainland, or continent.

[3] Certain epirogenic movements must necessarily have taken place to form the barriers by which the Laramie sea was cut off from the open oceans. Local unconformity among the Laramie strata which has been observed near the top of the group in Southern Wyoming indicates that certain other premonitory movements took place before the Uinta fold was well defined.

The inceptive portion of the Uinta fold is, of itself, by no means a conspicuous geological feature—first, because a broad valley or basin, which I have called Axial Basin, is formed along the greater part of its length by the erosion of the strata which have been uplifted there; and second, because the uplift is comparatively slight. A transverse section (Fig. 2) across Axial Basin shows the character of this portion of the fold, and it also shows the formations which are involved in it.

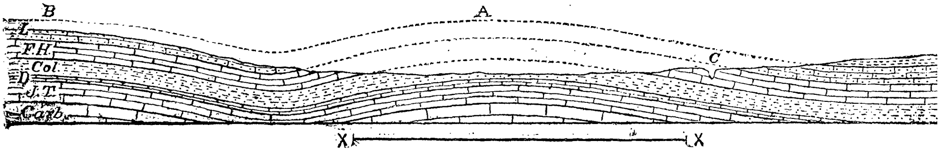

Fig. 2.—Transverse section across Axial Basin.

A. indicates the axis of the inceptive fold; B., the north base of Danforth Hills and a part of that uplift; C., Yampa River. Carb. indicates Carboniferous strata; J. T., Jura-Trias; D., Dakota Group; Col., Colorado Group; F. H., Fox Hills Group; L. Laramie Group; W., Wasatch Group. The line xx indicates proportionally the longer diameter of the Yampa Mountain upthrust, and also its position with reference to the inceptive axis.

Horizontal scale: 4 miles to the inch.

Vertical scale: 1-12 inch to 1,000 feet.

This comparatively slight fold becomes of great importance because of its evident relation to the great Uinta fold, and especially because of the presence upon its axis of the two upthrusts which have been already referred to, the presence of each of which is marked by an isolated mountain which rises abruptly out of Axial Basin. These are, Junction and Yampa Mountains, which are plainly outlying, isolated members of the Uinta Range.

The main portion of the Uinta fold terminates at its eastern end by a dip of the uplifted strata which is quite as abrupt as that at either side of it, and which carries them far beneath the surface of the adjacent lowland. Going now, only two or three miles eastward from this eastern terminus—where we have seen the later formations dip so suddenly from view—we come to the western border of Junction Mountain upthrust. Here we find the same strata to rise again, even more suddenly than they disappeared; and we also find that the formations of Palæozoic age—which constitute the high mountain-peaks of the Uinta Range only a few miles away—are here again uplifted, not only to the surface of the low land around the mountain, but to a maximum height of nearly two thousand feet above it. The strata involved in this uplift—which, because of its sharply-defined limits and of the vertical displacement of these strata, I have called an upthrust—occupy an elongate oval area, the extreme longer diameter of which is nearly twelve miles, and the shorter about four miles. The direction of the longer diameter, being in a northwestward and southeastward direction, is obliquely transverse to the general trend of the axis of the Uinta fold. In this respect, as well as by the peculiar character of displacement of the strata involved, the isolation of this upthrust is quite complete, although it lies so near the terminus of the main portion of the Uinta fold and upon the axis of its inceptive portion.

So sharply have the strata been uplifted in this displacement that they are either faulted or are nearly or quite vertical at a portion of each side of the upthrust, and they also dip very abruptly at other portions and around its ends. The Mesozoic formations, through which the older ones were forced, lie all around the mountain, but immediately adjacent to it they are largely covered from view by the strata of the Brown's Park Group, which lie unconformably upon them. The disturbance which these Mesozoic formations have suffered in that neighborhood beyond the base of the mountain is so slight that one cannot recognize it as having been connected with the upthrust movement. That is, their position as marking the presence of the inceptive portion of the Uinta fold and of certain subordinate uplifts does not seem to have been changed by the localized upthrust movement.

The Mesozoic formations,—which must have necessarily risen on the top of the older ones within the upthrust area,—have been removed by erosion, as has also a large part of the full thickness of the Carboniferous strata which came up beneath them. Therefore, only strata of Palæozoic age now enter into the structure of the mountain proper; while the upturned edges of the later ones, where they have not been sharply severed by faulting, lie around its base.

Going from Junction Mountain about sixteen miles along the axis of the inceptive fold, we pass all the way over the low lands of Axial Basin, the surface of which is there mostly occupied by the

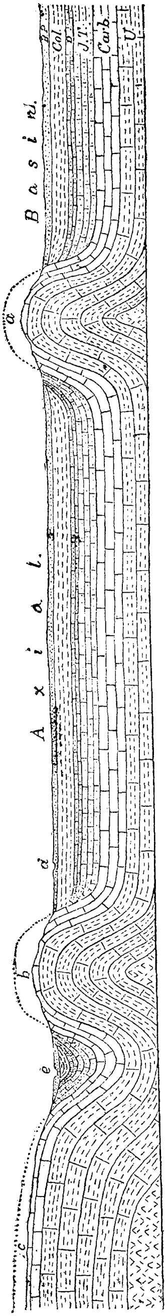

FIG. 3.—Section showing the eastern end of the Uinta fold, and the Junction, and Yampa Mountain Upthrusts.

Brown's Park Group, and reach Yampa Mountain, which rises directly upon that axis, as does Junction Mountain. Here we find that the description that has just been given of the Junction Mountain upthrust will apply in all essential respects to this. All around the base of Yampa Mountain the strata of the Brown's Park Group cover the immediate borders of this upthrust, even to a greater extent than they do those of Junction Mountain upthrust; but it is readily seen that the two mountains are essentially identical in structure and character, and that they have been produce in a similar manner. Yampa upthrust, however, is smaller than the other, and it is also much farther away from any other greatly displaced strata. Its outline is oval, the longer diameter, including all the strata involved,—not much exceeding seven miles in length,—and its shorter diameter is less than four miles. The longer diameter is nearly at right angles with that of Junction Mountain upthrust, and it is nearly transverse with the inceptive portion of the Uinta axis, upon which it rises. The relation of these two upthrusts to each other and to the main and inceptive portions of the Uinta fold is indicated by the section, Fig. 3.

a, Yampa Mountain; b, Junction Mountain; c, eastern end of the Uinta Range; d, Yampa River, before entering Junction Mountain; e, Snake River; U., Uinta Sandstone; Carb., Carboniferous strata; J. T., Jura-Trias; D., Dakota Group; Col., Colorado Group; B. P., Brown's Park Group.

Horizontal scale: 5 miles to the inch.

Vertical scale: 1-20 inch to 1,000 feet.

The amount of vertical displacement is about the same in each of these upthrusts, the extent of which is estimated from the thickness of the formations (as given in the foregoing table) and from the contour lines on the published topographic maps of that region. The contour line which cuts the top of the Uinta Sandstone in both these mountains passes along the southern side of Axial Basin, approximately at the base of the Laramie and the top of the Fox Hills Group. Referring to the preceding table, we find the thickness of the intervening formations to be eleven thousand eight hundred feet. It is therefore plain that the amount of vertical displacement in both these mountains is not less than is represented by those figures. That is, within the narrow and sharply defined limits that have been described, the strata of which both these mountains are composed have been thrust up a vertical distance of more than two miles,—which in the case of the Yampa upthrust is nearly equal to one-third of the longer diameter of the area affected by it.

As indicating that the amount of vertical displacement in these upthrusts is really greater than has been mentioned, it may be stated that the Fox Hills and Laramie strata referred to have themselves been elevated to a considerable extent in the adjacent Danforth Hills uplift (as shown by the section, Fig. 2). This figure will also serve to illustrate the relation of the Yampa upthrust to the inceptive fold and to the adjacent Danforth Hills uplift. That is, if within the space indicated by the length of the line xx the strata should be elevated until the base of the Carboniferous series reaches the place of the uppermost dotted line, the vertical extent and lateral restriction of the Yampa upthrust will be indicated.

It is true that the vertical displacement in the case of these two upthrusts is much less in amount than is that of the great fold; but the amount of displacement is far more remarkable in the case of the upthrusts than it is in the case of the fold, because of the very narrow limits within which the displacements in the former case have taken place. The narrow and sharply defined limits of these upthrusts, and the severing of the displaced portions of the formations from the great mass of each respectively, with little or no general disturbance of the latter beyond those limits, may be compared to the action of a large punch on being forced by great power through a number of thick iron plates. The comparison will be more complete if we conceive that the cutting-border of such a punch had become dulled at certain places, so that a part of the iron through which it was being forced would drag and not be sharply severed. Portions of the uplifted strata at the base of both these mountains seem to have thus dragged during their elevation; while other portions were sharply severed, as if the displacement had really been done by a huge punch acting from beneath, producing an ordinary fault there.

The evidence that the orogenic and epirogenic movements which have resulted in the present physical conditions in the Western portion of our national domain were coëval with each other, seems to be unmistakable, so far, at least, as the time-limit of each series of movements is concerned. But, considering for the present only the orogenic movements, it is evident that the uplifting force has been applied along certain lines with great inequality, both as regards the amount of force locally exerted and the duration of its application. That is, in the region especially referred to in this article there are indications that while the orogenic displacements now observable there were in progress there were local arrests and accelerations of the elevating movement, which produced a final diversity among them that did not exist in their inception.[1]

For example, the present structural condition of the Uinta fold seems to warrant the assumption that it was once, along its entire length, in the condition in which its inceptive portion now is, except for the presence of the upthrusts. Furthermore, that these upthrusts, as well as the main portion of the fold, continued their upward progress, while the present inceptive portion remained as it was when its elevation was arrested. There are other plain indications of the arrest and acceleration of uplifting force in that region; but the upthrusts rising upon the inceptive fold constitute the most striking examples.

The elevating force was not only strangely concentrated in the case of the two upthrusts, but it seems to have been applied in an unusual manner, especially when we consider the position of the longer axis of each with relation to that of the other, and also to that of the Uinta fold. It has been mentioned that the longer axis of the Junction upthrust lies in a northwest and southeast direction, and that of the Yampa upthrust in a northeast and southwest direction. Viewing these upthrusts only in relation to the Uinta fold proper, and regarding them as nearly or quite isolated portions of the same, one would naturally expect to find their longer axes coinciding with a line projected from the axis of the main fold, and he would also expect to find the intervening strata along that line to have partaken largely in the upward movement. That is, in view of the simplicity of the main portion of the Uinta fold, one might naturally expect that the uplifting force which was applied along its entire axis would have acted strongly and continuously, if not uniformly. But the foregoing statements show that neither of the upthrust axes coincide with such a line or with each other, and also that only a comparatively slight elevation of the strata has occurred along what I have designated as the inceptive portion of the Uinta fold.

These upthrusts are so extraordinary in their character that one instinctively desires to know how they were produced. I freely admit my inability to reply to such an inquiry in a satisfactory manner; and for the present I will offer only the following suggestion. Assuming—as the evidence seems to warrant us in doing—that the completion of the main Uinta fold and that of the Park Range were contemporaneous, or nearly so, they constituted ponderous buttresses at either end of the strongly-curved inceptive portion of the Uinta fold. It is not strange, therefore, that any elevating force that may have been applied along the axis of that inceptive fold—which stretched across the intervening space—should have been diversely, if not abnormally, applied.

NOTES ON THE GEOLOGY OF JOHNSON COUNTY, IOWA.

BY CLEMENT L. WEBSTER.[1]

THE superficial geology, or the study of the nature, origin, and distribution of the loose materials, or superficial detritus commonly denominated loess, drift, and aluvium, constitutes one of the most interesting as well as important fields for study that fall within the scope of investigation of the geologist.

The interpretation of the phenomena of the glacial period, the cause of the advance and retreat of the ice sheets, the condition of the climate and of the fauna and flora of the surface (now covered by drift) during the interglacial time, the extent and condition of

[1] State University, Iowa.